Raymond, SR 101, MP 60.35

Geology and Soils

Soils on this 591 feet long by 112 feet high east-facing slope are composed of marine sedimentary rocks that are weathered. Small shallow rapid landslides have occurred where these weathered clay layers have left slope sections exposed to water movement. With excess surface and subsurface moisture, these layers slipped and moved downhill into the ditch. To manage stormwater runoff, maintenance activities required clearing of these plugged ditch lines. In doing so, the base of the shallow rapid landslide was undercut, leaving a portion of the area with an exposed vertical face. During the year, the slope would "adjust," move again into the ditch line, leaving a larger head scarp exposed to surface and subsurface water movement.

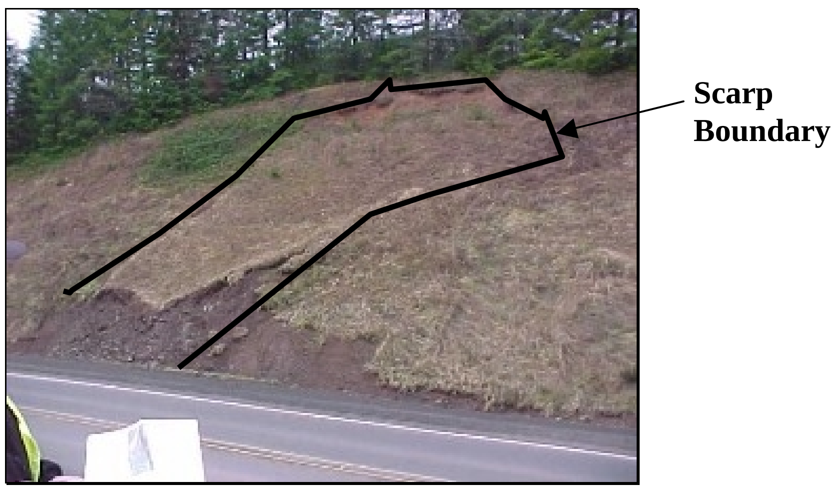

Figure 17. Area of Instability

Climate and Moisture

This southwestern Washington site receives an average of 85 inches of precipitation per year. The site receives very little snowfall. January is the only month that generally receives snow with on average 0.4 inches. No other snowfall is recorded during other months. Average maximum temperature is 72.9º F in August and average minimum temperature is 32.5º F in December. Further climate information can be found at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?waraym

Existing Vegetation

Onsite vegetation consisted of a very young community of Douglas fir, red alder, salal, palmate coltsfoot, common horsetail, and sword fern, with a good grass cover. There is a mature Douglas fir, western red cedar, and western hemlock community at the top of the slope which provides ample seed source for plant recruitment. Tree seedlings had been cut from the hillside on a regular basis, however WSDOT area maintenance personnel had not been involved in any tree removal at that site.

Opportunities And Constraints

This large slope, located on an outside curve, just north of the city of Raymond, is highly visible and receives ample rain throughout the year. The local climate and soils were supporting a diverse plant community. Trees and shrubs were needed to stabilize the slope, but were being cut on a regular basis. The PI and RA worked with road maintenance to select trees and shrubs that were acceptable to maintenance personnel.

In addition, WSDOT's chief engineering geologist thought this was a good candidate for a soil bioengineering project because the erosion process of the site involved surface erosion and a shallow rapid landslide. Both these erosion processes fall under the parameters of soil bioengineering techniques.

Design Solution

Raymond Soil Bioengineering Design 12-28-99

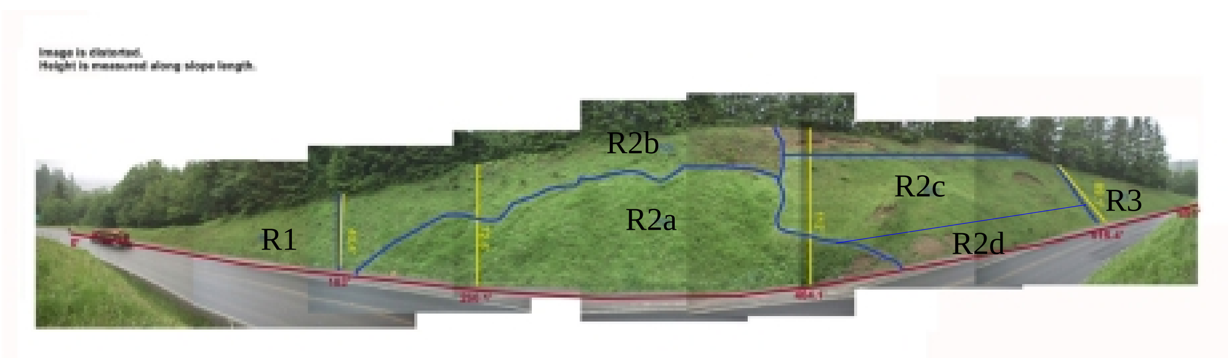

Figure 18. Raymond Research Site with Sub-areas

Area R1 and R3:

Primary focus is aesthetic.

- Plant with recommended mix of vegetation. Install bender board fencing to complement the existing bronze animal sculptures by local artists. Do not excavate a terrace behind the fencing (contrary to usual installation), add fill to create a planting platform. Be sure to mix the added soil with the original slope material.
- Construct cordons

Area R2:

Primary focus is stabilization.

R2a: Plant with approved mix of water-loving vegetation.

R2b: Plant with approved mix of vegetation.

R2c: Soil bioengineering. Starting at 6’ above cribwall at slope base:

- Construct a brush layer 5’ deep across the slope in the area.
- Construct a willow wall with a brush layer base across the slope above the brush layer.
- Alternate these two treatments at a maximum of 10’ intervals up to 75’.
- At 75’ above the cribwall, construct willow walls at 10’ intervals.
- Goal of these treatments: provide slope stability and easy access to planting areas.

R2d: Construct a live cribwall at the base of the slope.

- 183’ to 515.4’ = total length of cribwall (as seen from width markings on photo.
- From 260.1’ to 515.4’ construct cribwall 6’h X 6’w X 255.3’l.
- 77’ on either end, construct cribwall 5’h X 5’w.
- 10’ on either end, construct cribwall 4’h X 4’w.
- Flange ends to blend in with slope and to eliminate any potential “snagging” safety concerns.

Construction

Construction began with region Maintenance personnel using heavy equipment and two WCC crews using hand equipment on February 1, 2000. They began by excavating at the northern end of the site and installing the first cordon. Figure 19 shows the cordon construction after the bottom two logs have been placed in the terrace parallel to the slope.

Figure 19. Cordon Construction

Figure 20 was taken on February 10, 2000. It shows cribwall construction at the end of the first week of construction.

Figure 20. End of first week of construction.

Problems and Solutions During Construction

An email from the RA on February 15, 2000 reads:

> Some excitement here in Raymond this morning. About 80' into the 6X6 section of cribwall, an area approximately 70'W x 90' high began to slide as the excavator was removing the toe. It slid in one piece about 4' vertically in less than 30 seconds. I really hesitate to excavate any more of this area until we have a plan. I instructed the operator to continue to fill in the cribwall that has already been completed (to the right of the slide) as much as possible to counter weight the movement. The current cribwall is about 20' under the slide zone. Additional comments on the movement: the borders of the slide zone on the left is flaking away fairly normally (in response to the oversteepening and removal of the toe), but the one on the right seems to border a fracture area. The border on the right is almost vertical and the two areas are moving independently.

During site preparation for the base of the cribwall, the heavy equipment operator removed a portion of the slope toe the night before. The fresh cut was left unsupported overnight and when excavation resumed the next morning, the slope moved. The slope was oversteepened in the adversely oriented bedrock causing failure of the bedrock and colluvial soils overlying the bedrock. In different material this might now have happened, and if the site had not been excavated and left exposed overnight, this slope movement might have been prevented. For future projects, on sites of this size and with propensity for large movement, however, it is recommended that a slope stability analysis be a part of project design.

Figure 21. Slope Failure

Soil bioengineering work was halted in the area of the slide until an interdisciplinary team of experts could visit the site. On February 16^{th} the PI and research team and the region maintenance supervisor, Mike Whipple, held an interdisciplinary conference call discussing all safety concerns and issues. The group developed preliminary alternatives to be considered for the following day's field review.

On February 17, members of the research team visited the site with two WSDOT engineering geologists to determine the cause and to decide upon a course of action.

The research team recommended, and the PI approved construction could continue but with excavating no more than 10 to 15 feet of the slope toe at any one time. It was also recommended that exposure of personnel to the slope be avoided or minimized. Mike Whipple, Maintenance Area Superintendent, devised a plan to construct the log cribwall frames off site and to install them onsite in modules. No crew members were allowed behind or inside the cribwalls at any time.

The modular cribwall frames were constructed off-site by February 28, 2000. They were installed in two vertical sections so willow branches could be installed between the lifts and soil could be added and compacted with the excavator bucket. Installation can be seen in Figure 22. Each 15 foot cribwall framed section was cabled to the adjacent unit and to the ones above and below it.

Figure 22. Installation of modular live cribwall sections

The live cribwall and cordon construction was completed with these changes, without incident, on March 2, 2000. The Crews finished the Raymond project, with willow wall construction further up the slope and with plantings and straw mulch application, on March 28, 2000. Figure 23 shows the willow walls constructed above the live cribwalls.

Figure 23. Live Cribwall and Willow Walls

The Landscape Architect specified a mixture of cuttings and container plantings of the same species. These will be observed during the monitoring period to see if the cuttings thrive.

Species planted on this site are:

Twinberry (Lonicera involucrata)	50
Salmonberry (Rubus spectabilis)	100
Sword fern (Polystichum munitum)	50
Snowberry (Symphoricarpos albus)	100
Salal (Gaultheria shallon)	50
Scouler's Willow (Salix scouleriana)	50
Red Osier Dogwood (Cornus sericea)	100
Sitka Alder (Alnus sitchensis)	100
Ninebark (Physocarpos capitus or pacifica)	50

Figure 24 shows the entire project after completion.

Figure 24. Completed Soil Bioengineering Research Site

2000 Monitoring Results

- Trend is improving to stable
- No evidence of mass movement or surface erosion.
- Site is showing 95% vegetative cover.
- Structure survivability:
  - Cribwall structure - 90% new growth.
  - Willow wall structures – 30% show new growth.
  - Fascines – 10% show new growth.
- Native woody vegetation survivability:
  - Nursery stock – 80% survival.
  - Woody vegetation cuttings – 80% show new growth.
  - No difference in survival between nursery stock and cuttings of the same species.